ASYMMETRIC-FIELD ION GUIDING DEVICES

FIELD OF THE INVENTION

The invention in general relates to mass spectrometry, and in particular to electrodynamic ion guide structures suitable for use in mass spectrometers.

BACKGROUND OF THE INVENTION

Methods of mass analyzing chemical substances in the liquid phase often employ electrodynamic guiding structures for guiding ions into a mass analyzer. In a common approach, charged liquid droplets are generated in an ionization chamber using an atmospheric pressure ionization method such as electrospray ionization (ESI) or atmospheric pressure chemical ionization (APCI). The droplets are desolvated, and pass into a vacuum chamber through an orifice that limits the gas flow into the chamber. Gas with entrained ions exits the vacuum restriction and expands to form a shock structure. Ions and other gas can be removed from the silent zone of the shock structure by inserting a skimmer cone through a Mach disk into the silent zone, and allowing the ions to pass through a hole in the tip of the skimmer cone into the next vacuum chamber. The ions in the second vacuum chamber are captured by an electrodynamic ion guiding structure, and guided through the second chamber where more of the gas is pumped away. The ions next pass through a conductance-limiting aperture into a third vacuum chamber and into a mass analyzer. For further information on prior-art mass spectrometers and associated electrodynamic guiding structures see for example U.S. Pat. Nos. 4,963,736, 5,179,278, 5,248,875, 5,847,386, and 6,111,250.

Conventional mass spectrometers can suffer from large noise spikes in the mass spectrum generated by solvent droplets passing from the ionization chamber into the mass analyzer. In U.S. Pat. No. 5,750,993, Bier describes a method of reducing noise due to undesolved charged droplets or charged particles in an ion trap mass spectrometer coupled to an atmospheric pressure ionization source. A high DC voltage, for example about 300 V, is applied to an octopole guide or lens to block the passage of charged particles into the detector during analysis of trapped ions. The method described by Bier may not be optimally effective in preventing the passage of droplets into the analyzer.

SUMMARY OF THE INVENTION

In a preferred embodiment, the present invention provides a mass spectrometry apparatus comprising: an ionization chamber for forming ions of interest: a guide chamber having an inlet aperture in communication with the ionization chamber, and an outlet aperture; an electrodynamic ion guide positioned in the guide chamber, for guiding ions from the inlet aperture to the outlet aperture, a mass analyzer in communication with the outlet aperture, for receiving ions exiting the guide chamber through the outlet aperture; and an ion detector in communication with the mass analyzer, for receiving ions transmitted by the mass analyzer. The ion guide preferably comprises an inlet guide section for generating a first electrodynamic ion guiding field having a first generally longitudinal central field axis, situated such that ions transmitted through the inlet aperture enter the inlet guide section substantially along the first central field axis; and an outlet guide section longitudinally concatenated with the inlet guide section, for generating a second electrodynamic ion guiding field having a second generally longitudinal central field axis displaced from the first central field axis and substantially aligned with the outlet aperture. Displacing the inlet and outlet field axes allows reducing the noise caused by droplets, photons, and other neutral particles, while at the same time inserting the ions of interest along the central axis of the field. Inserting the ions of interest along the central axis of the guiding field allows maximizing the capture efficiency of the guide.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing aspects and advantages of the present invention will become better understood upon reading the following detailed description and upon reference to the drawings where:

FIG. **1** is a schematic diagram of a mass spectrometry analysis apparatus according to a preferred embodiment of the present invention.

FIG. **2** shows a schematic longitudinal view of an electrodynamic ion guide comprising a plurality of progressively-narrowing segments defining three guide sections, according to a preferred embodiment of the present invention.

FIG. **3**-A shows a schematic transverse view of one of the segments of the ion guide of FIG. **2**.

FIG. **3**-B shows a transformer arrangement suitable for generating a symmetric quadrupole guiding field, according to an embodiment of the present invention.

FIG. **3**-C shows a transformer arrangement suitable for generating a guiding field having a symmetric quadrupole component and an asymmetric dipole component, according to an embodiment of the present invention.

FIG. **4**-A shows a schematic longitudinal view of an ion guide comprising a plurality of geometrically-identical segments defining two guide sections, according to an embodiment of the present invention.

FIGS. **4**-B and **4**-C show schematic longitudinal and transverse views, respectively, of an ion guide comprising segmented parallel rods, according to an embodiment of the present invention.

FIG. **4**-D shows a schematic longitudinal view of an ion guide comprising segmented tilted rods, according to an embodiment of the present invention.

FIGS. **5**-A through **5**-L illustrate exemplary computed trajectories for ions passing through ion guides under several conditions, according to the present invention.

FIGS. **6**-A and **6**-B illustrate computed electric dipole fields for a flat plate and a round rod electrode configuration, respectively, according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

In the following description, it is understood that each recited element or structure can be formed by or be part of a monolithic structure, or be formed from multiple distinct structures. For example, an input blocking structure/wall and an output blocking structure/wall can be provided as part of a single monolithic housing. A set of elements is understood to include one or more elements. Two concatenated elements (e.g. guide sections or segments) can be adjacent or can be separated by intervening elements. A voltage source may include one or more electrical nodes/leads and/or other electrical components (e.g. inductors, capacitors, transformers) generating desired voltage values.